# A sub-microsecond pulsed plasma jet for endodontic biofilm disinfection

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**Résumé**

The antimicrobial effect of a non-thermal plasma jet, employing sub-microsecond pulses, against endodontic biofilms, was studied with an *in vitro Enterococcus faecalis* biofilm model and a pilot *ex vivo* saliva biofilm model. The studies are to assess the application feasibility of the plasma for root canal disinfection.

**Abstract**

A pulsed, tapered cylindrical plasma jet, several centimeter long and <2 mm in diameter, has been generated by a concentric tubular device for root canal disinfection [1]. This plasma dental probe is typically powered with ~100 ns, 1-2 kHz, multi-kilovolt electric pulses and filled with 1-5 SLPM (standard liter per minute) He/(1%)$O_2$ flow. The energy per pulse was measured to be 1.2 – 1.8 mJ, resulting in less than 2 W average power when the plasma device operates at 1 kHz [2]. This low power, pulsed, plasma jet consists of ionization fronts propagating away from both electrodes at speeds of the order of $10^7$ cm/s [3]. Optical emission spectroscopy reveals that reactive plasma species including O and $O_3$ are present and may play significant roles in the bactericidal process [1, 4]. We report here an *in vitro* study of the antimicrobial effect of the room temperature plasma jet against monolayer *Enterococcus faecalis* biofilms on bovine dentins. Resultant colony-forming unit counts were associated with changes in bacterial cell morphology observed using scanning electron microscopy (SEM) following the treatment and control. Treatment of dentin discs cultivated with *E. faecalis* monolayer biofilms with the plasma (average power ≈ 1W) for 5 min resulted in 92.4% kill ($P < 0.0001$). Severe disruption of the cell membranes were observed for the plasma treatment group, while the morphology of the cells remained intact for the negative control group, as shown in Fig. 1. In addition, a pilot *ex vivo* test was also conducted to examine the bactericidal effect of the plasma against saliva-derived biofilms cultivated in human root canals. Fig. 2 demonstrates the plasma jet impinging into a root canal. Plasma treatment of two root canal specimens for 5 min resulted in removal of the biofilms for a depth of 1 mm in the root canal of one specimen, and only spottily cleared dentinal surfaces occupied with physically disrupted bacterial biofilms for the other specimen. Improvement of the disinfection results is in progress through the optimization of the technology that will enhance the bactericidal effect and deliver the plasma jet into the entire root canal. In summary, the antimicrobial effects of the plasma jet against single or multi species biofilms on dentinal surfaces or in root canals have been demonstrated. We conclude that this non-thermal pulsed plasma-based technology is a potential alternative or supplement to existing protocols for root canal disinfection. This work is supported by a grant from the National Institute of Dental and Craniofacial Research (NIDCR), one of the National Institutes of Health (NIH) in the U.S. Department of Health and Human Services.

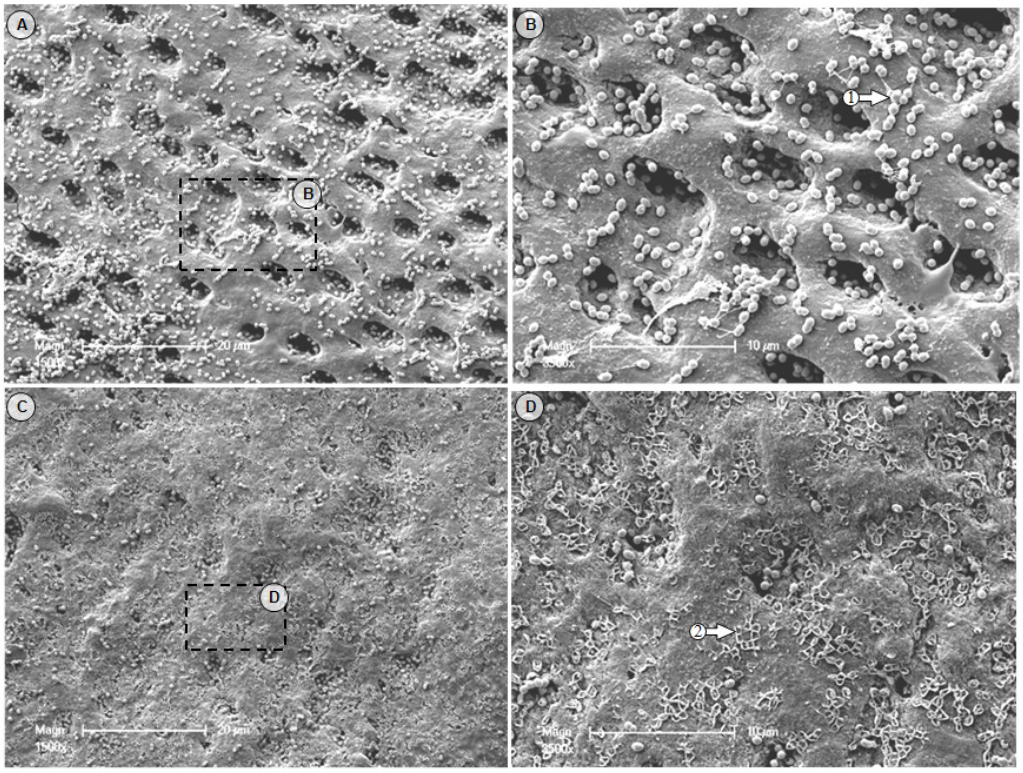


Fig. 1: SEM: (A) monolayer *E. faecalis* biofilms cultivated on bovine dentin discs without treatment (the negative control); (B) the same monolayer biofilms at higher magnification (3500x): *E. faecalis* cells appear morphologically intact (arrow 1); (C) after the plasma treatment (He/(1%)$O_2$ plasma, 5 SLPM, 5 min); (D) the same plasma treatment group at higher magnification (3500x): membrane integrity severely compromised or damaged cells were mostly observed (arrow 2).

Fig. 2: The room temperature plasma jet impinging into a root canal

## References

[1] C. Jiang, M.T. Chen, A. Gorur, C. Schaudinn, D.E. Jaramillo, J. W. Costerton, P.P. Sedghizadeh, P.T. Vernier, M.A. Gundersen, Plasma Process. Polym. **6** (2009) 475.

[2] C. Jiang, M.T. Chen, A. Gorur, C. Schaudinn, D.E. Jaramillo, J.W. Costerton, P.P. Sedghizadeh, P.T. Vernier, M.A. Gundersen, IEEE Trans. Plasma Sci. **37** (2009) 1190.

[3] C. Jiang, M.T. Chen, M.A. Gundersen, J. Phys. D: Appl. Phys. **42** (2009) 232002.

[4] C. Jiang, V. Puech, L. Magne, P. Jeanney, 62nd Gaseous Electronics Conference, Saratoga Springs, NY, USA, October 22 (2009).